Airborne geophysical coverage of Western Australia

by S. H. D. Howard

Abstract

Western Australia's vast size presents a formidable challenge to obtain statewide coverage of pre-competitive geophysical data of sufficient resolution to be of real use to explorers. The Western Australian Government's investment of $12 million, for a four-year regional geophysical survey program starting in 2004–05, is a welcome boost to the capacity of the Geological Survey of Western Australia to provide much-needed regional aeromagnetic and radiometric coverage for some of the State's most prospective areas. However, considerable additional funding will be required to complete basic data coverage of Western Australia as recommended by recent State and Federal government reviews.

While there is little doubt of the value of government investment in pre-competitive geoscience information, there is no simple solution to the trade off between extent of coverage and resolution detail in airborne geophysical surveys. In this context, the Geological Survey has adopted a strategy that seeks to optimize the effect of the present funding initiative by integrating new flying programs with the purchase of existing data. Its four-year plan seeks to complete 400 m-resolution coverage of magnetic and radiometric surveys over areas where Precambrian rocks are exposed or within 300 m of the surface. Commencing with surveys in the southern Yilgarn, priority areas for future work include the Murchison–Gascoyne region, the eastern wheat belt, the Albany–Fraser Orogen between Esperance and Warburton, the Musgrave–Arunta region on the Western Australia border, and the west Kimberley. There are also plans for collection of other data such as orthophotography and hyperspectral sensing, geochemical and gravity surveys, and some deep crustal seismic traverses in key areas of the State.

Introduction

In February 2004 the Premier of Western Australia announced his intention to invest an additional $12 million over the next four years to double the area of the State covered by modern airborne geophysical surveys. The funding was confirmed in May 2004 with the inclusion of the 'Geoscience Information Program – Minerals' in the WA State Government budget for 2004–05, and the allocation of the first tranche of $3 million as an addition to the standing budget of the Geological Survey of Western Australia (GSWA) for the provision of Geological Services (Department of Treasury and Finance, 2004).

This initiative has been welcomed by the minerals industry, and is a valuable boost to the capacity of GSWA to provide much-needed regional aeromagnetic and radiometric coverage for some of the State's most prospective areas. However, the fact remains that the present pre-competitive airborne geophysical coverage in Western Australia is still at a very low level, with only about one third of the State presently covered by non-proprietary, appropriate-resolution* surveys.

While it is easy to accuse governments of being niggardly, the vast size of Western Australia (which, at 2.5 million km^2, is one third of the total area of Australia and more than a quarter that of China, Canada, or the United States) requires a disproportionately higher level of expenditure in relation to the size of the economy for the provision of suitably detailed geophysical coverage.

Not surprisingly, it has never been an easy task to convince Western Australian State Governments and the Federal Government and their Treasury Departments to invest funds in the acquisition of regional pre-competitive geophysical data in Western Australia at a rate that might be considered desirable by explorers.

This article summarizes the background to the current state of publicly-owned airborne geophysical coverage of Western Australia, reiterates the rationale for government funding of pre-competitive information, and, in the context of the dilemma between coverage and detail, outlines GSWA's data-acquisition strategy and four-year plan.

Background to the current geophysical funding initiative

Previous airborne survey funding initiatives in WA

The latest funding boost occurs 20 years after the first such specific initiative funding in 1984–85, when, over four years, $282 000 were allocated for the purchase of about 200 000 line-km of non-exclusive, commercial airborne magnetic and radiometric data in the Eastern Goldfields and Murchison. The total area covered by these 200 m line-spaced datasets was the equivalent of about twelve 1:100 000 map sheet areas (30 000 km^2), or slightly more than 1% of the area of the State. These purchases did not include the publication rights to the digital data, only the right to publish hard-copy contour maps of the data.

1990–91 saw the first injection of Federal Government funds for an airborne geophysical survey in Western Australia at a line spacing of less than 1600 m — at that time the standard adopted for large-area government surveys — when the Bureau of Mineral Resources (now Geoscience Australia) purchased 45 000 km of existing commercial 400 m line-spaced data over the Edjudina 1:250 000 sheet area. This was followed by the next injection of State airborne survey funding of almost $250 000 in 1991–92 for the purchase of about 110 000 line-km of non-exclusive commercial data in the Kanowna and Kurnalpi regions.

In 1993, the State Government introduced a focused, longer term program for the provision of regional geoscience data with the announcement of a $20 million, four-year 'Accelerated Mapping Initiative', including $500 000 per year for airborne geophysical data acquisition. Over the course of the next four years, working in close cooperation with Geoscience Australia (then the Australian Geological Survey Organisation) to optimize the use of State and Commonwealth funds, GSWA spent $2.2 million on new airborne magnetic and radiometric surveys flown at a line spacing of 400 m, and purchases of existing non-exclusive and proprietary company survey data. By the end of 1996–97, some 1.3 million line-km of publicly owned survey data at 400–500 m line spacing or less was available over large areas of the central and northern Yilgarn, western Pilbara, and Kimberley.

The government extended the Accelerated Mapping Initiative funding for a further four years to 2000–01. With the inclusion of Commonwealth-funded surveys through Geoscience Australia, by the end of 2000–01 total public coverage had increased to 2.1 million line-km over almost 500 000 km^2 of the State.

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* In this context, resolution refers to the spacing between survey lines. Although the along-line sampling rate and the flying height also affect data resolution, their impact is less important for large-area surveys until the survey-line spacing is 100 m or less. What constitutes 'appropriate-resolution' depends on a number of factors, which are discussed more fully in the text.

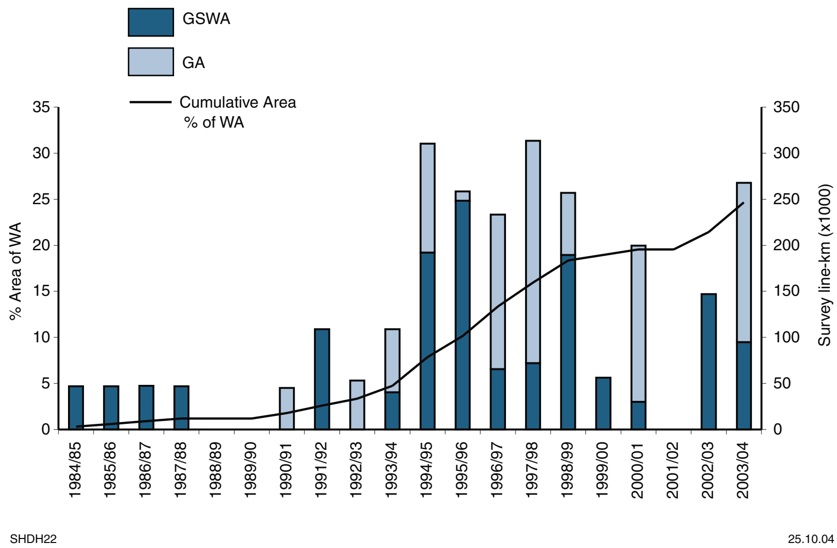

Figure 1. Annual government airborne geophysical data acquisition in Western Australia (1984–2004)

During the next three years, GSWA was able to direct a total of $1.1 million towards new surveys in the west Musgrave and west Tanami regions and in the northern Murchison. With Geoscience Australia surveys in the central and south Murchison, by the end of 2003–04 a further 415 000 line-km of data covering 128 000 km^2 had been added to the government-owned data inventory in Western Australia, taking the total to approximately 2.5 million line-km over about 600 000 km^2 (Fig. 1).

Publicly accessible data also includes proprietary data flown by commercial survey companies on a non-exclusive basis, and private exploration company data made available for public sale or, when possible, released by the Department to ‘Open File’ for public access.

Taking all these datasets into account, the airborne geophysical coverage of Western Australia is much improved although still well below 50% of the State’s area. Figure 2 shows the spatial distribution of government-owned, commercial, and otherwise publicly available airborne geophysical datasets in June 2004.

Recent government inquiries

The Fardon Report

In mid-2000, as the four-year extension to the Accelerated Mapping Initiative was drawing to a close, the government commissioned a review of the programs and funding of GSWA. The Task Force, lead by Dr Ross Fardon and including one representative from the WA exploration industry and one from the State Treasury Department, made the primary recommendation for a ‘significant increase in funding for GSWA from the current $17 million to about $40 million per annum’ together with ‘catch-up’ of about $90 million over seven years.

Among its detailed recommendations for the application of increased funding, the Task Force proposed expenditure of $60 million over seven years ($8.5 million per year) for the acquisition of aeromagnetic and radiometric data. This, it was recommended, should include 100 m line-spaced surveys over about 750 000 km^2 of ‘highly prospective areas’ ($5.4 million per year; $38 million over seven years) and 400 m line-spaced surveys over the remaining 1.75 million square kilometres of the State ($3.1 million per year; $22 million over seven years).

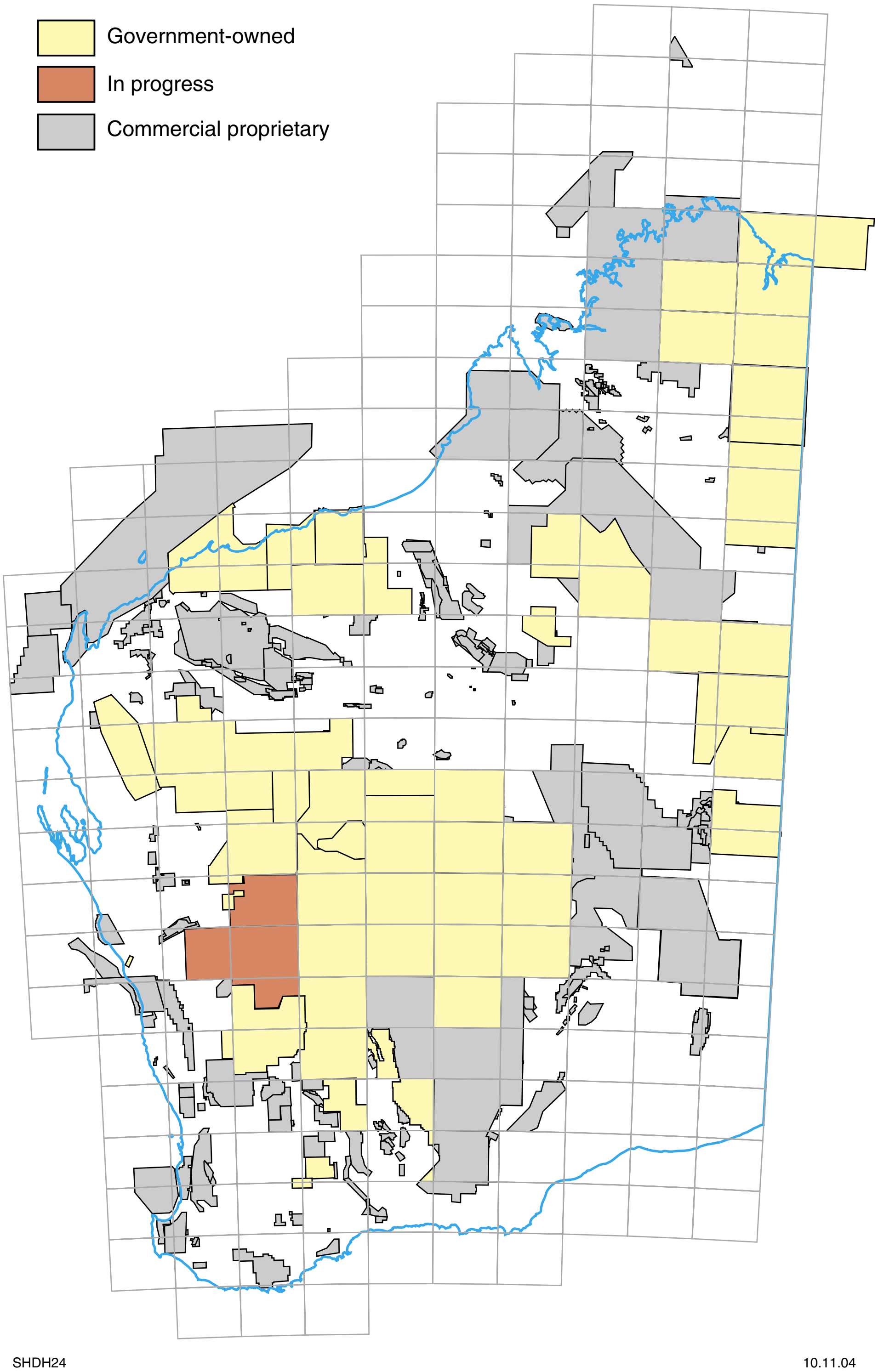

Figure 2. Publicly accessible airborne geophysical datasets in Western Australia in June 2004

The Fardon Task Force also proposed an investment of $14 million over seven years for the acquisition of 2 km × 2 km gravity data over some 25% of the State.

The Bowler and Prosser Inquiries

The State Government's response to the Fardon Task Force report was cast in the context of an extended period of low investment in mineral exploration generally and in greenfields exploration (defined as more than 5 km from existing mines) in particular. Activity data indicated that mineral exploration activity in 2001–02 had fallen 47% from its peak of $705 million in 1996–97, and there were few signs of improvement. Exploration expenditure in greenfields areas had fallen 63% during this period.

The government decided to review not only the issue of pre-competitive geoscience information in Western Australia (the primary concern of the Fardon Task Force), but also to investigate other factors that might be contributing to the exploration downturn. A Ministerial Inquiry, led by John Bowler MLA, was established in April 2002 with the objective of recommending actions to stimulate the level of expenditure necessary to sustain the future of the resources sector in Western Australia.

The woes of the mineral exploration sector were not confined to Western Australia, and concerns were also being expressed at a national level. In May 2002, the Federal Minister for Industry, Tourism and Resources referred a similar inquiry — albeit with a broader scope — to the House of Representatives Standing Committee on Industry and Resources chaired by Geoff Prosser MP.

Not surprisingly, both inquiries found there were a number of factors that impact on exploration activity and — also unsurprisingly given Western Australia's pre-eminent position in the Australian exploration sector — the factors identified in both inquiries were essentially the same (Bowler, 2002; Prosser, 2003):

- Investment attractiveness (capital raising and taxation)
- Perceptions of prospectivity (pre-competitive geoscience information)
- Geoscience education, research, and development
- Titles systems (security of tenure)
- Access to land (Native Title and environmental issues)
- Approval regimes
- Community understanding of the resources sector

While specific recommendations in the two reports (33 from Bowler; 28 from Prosser) were different both in emphasis and priority, both inquiries placed very significant emphasis on the provision of pre-competitive geoscience data.

Bowler also made the more specific recommendations that the base level of activity within GSWA should be maintained at no less than its current level, and that regional geophysical data coverage, especially in greenfields regions, should be expanded with a special allocation of $24 million over six years.

The Minerals Exploration Action Agenda

Almost in parallel with the Prosser (House of Representatives) inquiry, in September 2002 the Federal Minister for Industry, Tourism and Resources announced the development of the Minerals Exploration Action Agenda (MEAA) to address the decline in exploration in Australia. A Strategic Leaders Group (SLG) of industry and government representatives was formed to identify the priority issues and assess possible solutions. The SLG presented a report to government in July 2003.

The SLG, supported by four subsidiary working groups, identified the priority issues impacting on exploration investment in Australia: difficult access to land and finance, and increasingly inadequate geoscience data and mineral exploration research (SLG, 2003). These issues largely echoed the sentiments of the Bowler and Prosser inquiries.

Included among the SLG's 12 recommendations was a call for greater government investment in pre-competitive geoscience information. This was endorsed by the Ministerial Council for Mineral and Petroleum Resources in September 2003, with a proposal for a ten-year, $25 million per year program for pre-competitive geoscience information to be co-funded by the Commonwealth and the States.

In July 2004, as part of the Federal Government's 'Resources Exploration Strategy', the Minister for Industry, Tourism and Resources released *Minerals Exploration — The road to discovery: the Minerals Exploration Action Agenda (MEAA)*. Among the 'range of practical measures to ensure the long term sustainability of the minerals exploration industry and the mining industry which it underpins', was the call for a 'major pre-competitive geoscience survey program to achieve national coverage of basic geoscience datasets to modern standards' (Department of Industry, Tourism and Resources, 2004).

However, additional funding for such a program was not made available in the Federal budget for 2004–05; it remains to be seen whether it will be forthcoming in the next budget.

The rationale for government investment in pre-competitive geoscience information

The value of exploration

The value of exploration to the economy of the State is widely accepted not simply as an article of faith, but because:

a) it is patently obvious that — rare serendipitous finds aside — discoveries and resources development will not occur without prior exploration;

b) the correlation between exploration and resources development can be determined (at an aggregated level) by statistical and economic analyses*;

c) the impact of exploration expenditure on the economy can be readily estimated by econometric modelling†; and

d) even if the exploration is unsuccessful, there is still a contribution to the economy (and to the State coffers) from the exploration expenditure itself and its flow-on multiplier effects (e.g. Clements and Qiang, 1995).

Even taking into account concerns about any potentially negative cultural and environmental impacts, there is little argument of the value that exploration has in economic terms. It is more difficult by far to measure the effect on exploration activity of pre-competitive (geoscience) information and thus set a quantum on how much government funding should be allocated to it. While various qualitative studies have been conducted (a number are referenced in a recent review by Hogan, 2003), there appear to be very few accepted quantitative analyses.

* For example, over 17 years from 1985 to 2002, the estimated finding cost for gold in Australia was around A$60–70/oz for grassroots exploration, compared with an estimated A$12–18/oz for mine-site exploration (Schodde, 2003).

† An analysis in Appendix 3 to the Bowler Report (Bowler, 2002) suggests that an $80 million decrease in annual exploration expenditure for five years (in Western Australia) will have detrimental effects on the State Government income flows in terms of losses in payroll tax, stamp duty, royalties, and other tax incomes, resulting in a total revenue loss of more than $1.5 billion (undiscounted) over 20 years. In contrast, an annual increase in exploration expenditure of $100 million for five years is likely to have a positive impact on the State's economy, resulting in a total revenue increase of more than $1.7 billion over 20 years (Department of Mineral and Petroleum Resources and Department of Treasury and Finance, 2002).

The link between exploration and pre-competitive geoscience information

Exploration carries two inherent classes of risk. One is what may be termed 'country risk'*. As echoed by the recent government reviews, this risk includes a number of factors, the impact of which will vary from company to company and country to country. These include land access, fiscal and legal framework, mining law, negative environmental legacies, security of tenure between discovery and mining, and, in some cases, the level of corruption that is prevalent in a target country (Bavinton, 2004). But before evaluating these various risk factors, an exploration investor must select an area to assess by considering the other type of inherent exploration risk — 'geological risk', often referred to as 'perceived prospectivity' or the likelihood that an economic deposit will be found in the area.

Geological prospectivity is the first criterion for selection of a geographical location for exploration and can make a dramatic difference to the level of exploration activity. For example, in a period when global exploration expenditure dropped from US$5 billion in 1997 to US$2 billion in 2002 (and echoed in the level of exploration investment in Australia), investment in the search for deposits in Finland *increased* from 25 million euro in 1997 to over 40 million[†] in 2002 (Sailas, 2003).

Public or pre-competitive geoscience information is what illuminates the geological potential or prospectivity of a country or area for evaluation by explorers. It follows that the amount, quality, and accessibility of pre-competitive geoscience information for a particular area are likely to be critical determinants of exploration activity in that area. Not surprisingly, again, this was a conclusion reached by the three recent government reviews.

While the qualitative link between pre-competitive geoscience information and exploration activity is well established, less well defined is the quantitative link. Estimates provided to the Prosser Review suggest that every $1 spent by the government in the provision of pre-competitive information stimulated private exploration expenditure from $3 to $15, with an average of $5[‡].

This figure is compatible with a 1999 Canadian estimate that 'every $1 million of government investment to enhance the Geoscience knowledge base will likely stimulate $5 million of private sector exploration expenditures which, in turn, will result in discovery of new resources with an average in situ value of $125 million' (National Geological Surveys Committee, 2000).

These estimates of value might well be significantly higher if they were to include a component for the value of the information for use by other sectors of the economy and by governments as a basis for decision-making support on issues of land use and infrastructure.

Of course, if it were that simple and clear-cut, government treasuries would be throwing money at pre-competitive geoscience. After all, if the models and estimates are correct, then an additional $20 million per year of government investment in pre-competitive information for five years will generate an increase in exploration expenditure of $100 million per year, which in turn will lead to an increase in (undiscounted) revenue of $1700 million over 20 years. Even undiscounted, 1700% return over 20 years is not a shabby investment.

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* Here the term 'country risk' is not used synonymously with 'sovereign risk' but includes sovereign risk, which is generally taken to mean the risk of actions by the government that might prove detrimental to a project.

† While these expenditure figures may seem small in relation to mineral exploration expenditure in Western Australia, if they are normalized in terms of currencies and the respective land areas, they translate into an increase in expenditure from about $\$123/km^2$ to $\$197/km^2$ for Finland compared with a decrease in Western Australia from $\$278/km^2$ to $\$146/km^2$.

‡ South Australia: $3–$5 (Prosser, 2003, paragraph 4.23, p. 53); Queensland: $15; Geoscience Australia: Average of $5 (Prosser, 2003, paragraph 4.24; p. 54).

These arguments about the quantitative value of pre-competitive geoscience information in attracting exploration investment are less than convincing to some of the holders of the community's purse strings.

However, because the qualitative arguments cannot be convincingly refuted, they cannot be entirely ignored. But the lack of a strong quantitative link and the fact that any returns are almost invariably long-term seem to result in an inconsistent commitment and, hence, very variable levels of funding for this purpose by most governments. Where funding boosts do occur, they often appear to be a reactive response to crises in the resources sector rather than a forward-looking approach to ensure its longer term sustainability.

Resolution and coverage in regional geoscience surveys

The resolution of a geoscientific dataset is a function of the density and precision of observations: the greater the density of observations and the better their precision, the more detailed is the scale of the geological features that can be mapped. Because precision tends to be largely a function of the available technology at any given time, resolution becomes a question of data density.

Regardless of whether governments are reluctant or lavish providers of funds for the acquisition of pre-competitive geoscience information, there is the perpetual question of what is the 'appropriate' resolution in the data. Too much detail, and the government risks becoming involved in the exploration process itself (which some governments choose to do). Too little, and it fails to have the desired effect.

The key factors governing the 'appropriate' degree of resolution are the coverage that is required and the scale of geological features that are to be mapped.

Airborne magnetic survey resolution

The observation density and, hence, the resolution of an airborne geophysical survey, particularly a survey flown with the objective of large-area mapping, tends to be almost wholly determined by the spacing between the survey lines (and the line direction in relation to the geology). Certainly the actual data resolution is a function of the flying height, the along-line sampling interval, and the measurement precision, but for the purposes of display and qualitative interpretation — except in certain specific-objective surveys — their impact is much less important until the line spacing is about 100 m or less.

In Figure 3 are shown two aeromagnetic images over the same area; the image in Figure 3a was produced from a dataset flown at one eighth of the line spacing of that in Figure 3b. The difference is stark. On the basis of the magnetic images, the two areas could almost be different. Why should one even consider spending funds on the coarser survey if it cannot decipher the detail clearly demonstrated in the higher resolution survey?

Would it were so simple. While nature contains a mind-numbing infinity of detail, our resources to gain access to that detail are all too finite (in which dichotomy lies the economist's claim to relevance). In almost all cases, the choice we are faced with is not between the 'equi-area' options illustrated in Figure 3 but the 'equi-cost' options illustrated in Figure 4; in other words, the choice between coverage and scale.

The choice between coverage and scale

Governments and explorers, both with limited funds, are faced with the same dilemma: the choice between a detailed survey in a restricted area and a coarser survey over a larger area.

Besides the community demand for equity of treatment between different areas of the country, there are some strong drivers for governments to place a higher priority on uniform coverage of a broad area at coarser resolution than on more-detailed coverage over a restricted area.

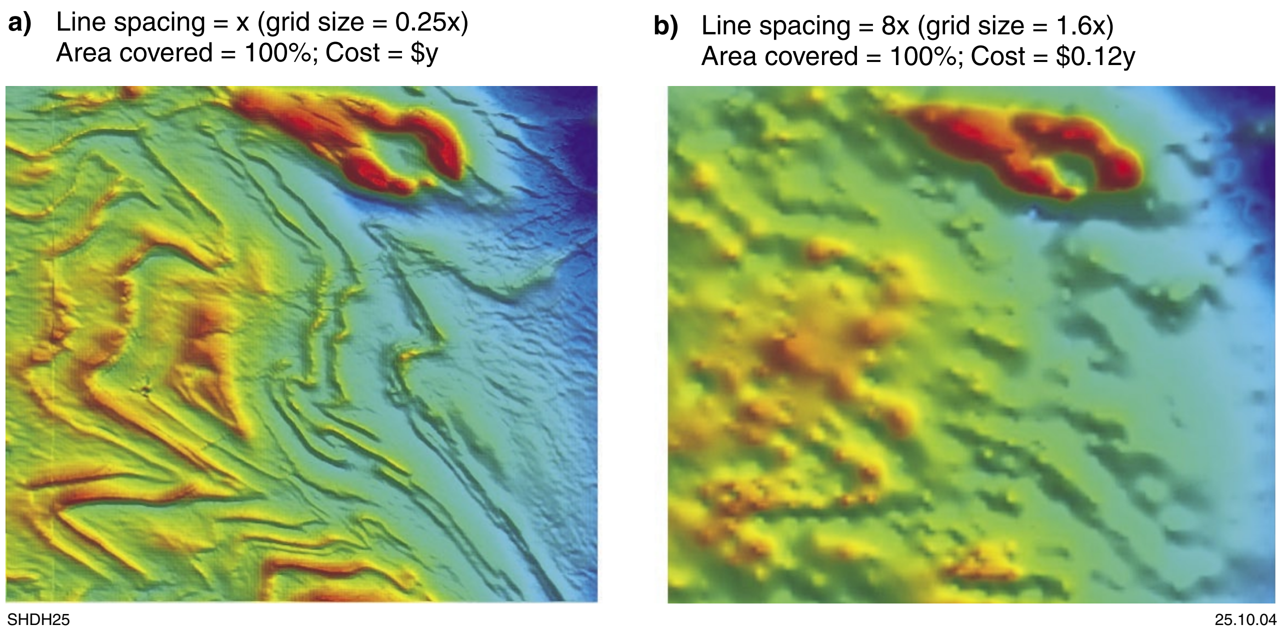

Figure 3. Illustration of equi-area aeromagnetic data coverage options. Location and scale deliberately suppressed

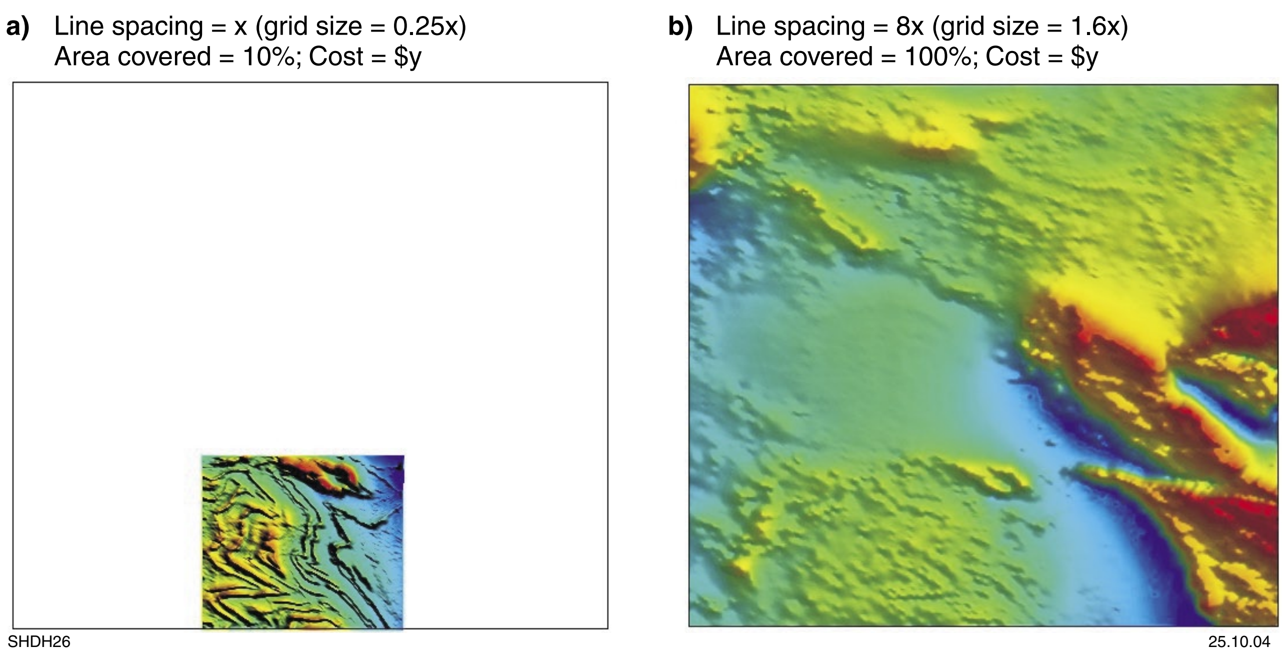

Figure 4. Illustration of equi-cost aeromagnetic data coverage options. Dataset in illustration a) is the same as that shown in Figure 3a. Processing stretches adjusted separately in each dataset

Almost all of the billions of dollars spent annually on exploration around the world are accounted for by explorers who take the approach of interpreting (coarser) datasets over larger areas to infer the location of smaller areas for targeted and detailed exploration activity (in which activity lies the geoscientist's claim to relevance). Therefore, if overview data from an area are publicly available at zero or minimal cost, the area is likely to be more attractive to an explorer than if the data were not available; it is the primary reason why government-provided pre-competitive information is so important as an incentive for private exploration*.

Another, also very strong driver is the demand for uniform regional geological coverage from the professional geoscientists and geoscience organizations who provide indispensable technical advice to governments and corporations. These professionals are well aware that in geology, as in most scientific disciplines, major new insights can be gained from the analysis of data patterns over extensive areas, thus providing a context into which detailed observations can be placed and better understood. A dramatic example of this is the impact of the 1950s measurement and discovery of the linear magnetic anomaly patterns in the North West Pacific and their interpretation in the 1960s to lend support to the revolutionary theory of plate tectonics.

Because a government-initiated program to provide large-area coverage only has any plausibility if it is programmed to be done in a specified time frame, the area, time, and budget together serve to set a limit on how detailed such a survey can be.

The situation is not stable. Once uniform pre-competitive data coverage at any particular resolution has been acquired over an area, there will be pressure to improve that resolution, either because of advances in technology or the availability of higher resolution coverage in other, competing areas for exploration investment.

Scale as a determinant of appropriate resolution

If the area that is to be surveyed is determined, the size of geological features that are to be mapped can be an absolute determinant of the required resolution, whether for exploration or regional surveys. For example, the maximum line spacing that can minimally resolve a steeply plunging stratigraphic fold closure is half the 'wavelength' or the 'amplitude' of the fold depending on the line direction relative to the strike (Fig. 5).

In practice, things are not quite as simple because geological features are not regularly defined. Nor, in exploration, can the 'size of target ore body' be used as a strong criterion unless one is confident that the target deposit is 'geologically well-behaved', which is generally not the case.

Therefore, 'map depiction scale' (i.e. the scale at which a depiction of the geology or geoscience data is to be displayed for the purposes of analyses or to make comparisons with the geology of another area) is often used as a surrogate for 'geological scale'. Thus, the detail of geological features that one might expect to find on a map at 1:100 000 scale is different from what one would expect on a map at 1:500 000 scale.

This idea of 'map depiction scale' can be used to provide a convenient rule of thumb for determining the appropriate airborne survey resolution for coverage of a given area: a line spacing that is represented by about 1 mm at the intended

* There are also economic arguments. If the data were not available and two explorers both competitively undertook an overview survey in the same area, the duplication of work would represent a decrease of economic efficiency as the total sum (of both explorers' limited funds) spent on detailed, targeted exploration would be less than that if the overview survey was conducted only once. This is further reason for government-funded pre-competitive information and is what underlies the inclusion in most countries' exploration legislation of the requirement to make previous exploration data available to subsequent explorers.

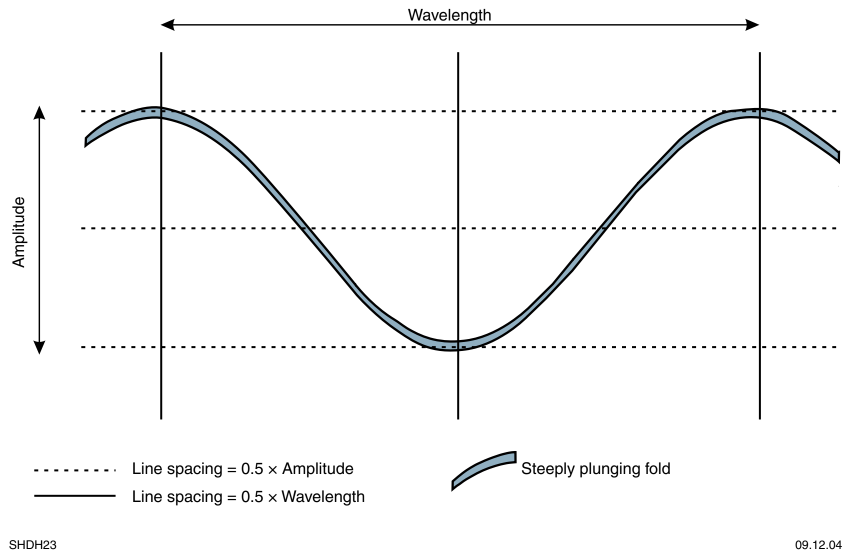

Figure 5. Survey resolution and geological scale

presentation scale. So an appropriate resolution survey for a standard 1:250 000 scale area of 1° latitude by 1.5° longitude (about 100 km × 150 km in Western Australia) might have a line spacing of about 250 m (ranging from about 100 m, or 0.4 mm at presentation scale, to about 400 m, or 1.6 mm at presentation scale).

These concepts of coverage and scale are important in understanding the scope of the current funding initiative and as a basis for the GSWA data-acquisition strategy.

Scope of the current funding initiative

The present funding program of $12 million per year over four years for the provision of regional geophysical data is an order of magnitude more than previous governments' investments for this purpose. Representing an addition of about 25% to GSWA's standing annual budget, it will make a significant difference to the level of pre-competitive regional geophysical data coverage in Western Australia.

To appreciate how significant, consider that this level of funding fully applied at the current cost of airborne magnetic and radiometric surveys represents coverage of about 800 000 km^2 or about 30% of the State's total area (at 400 m line spacing). If realized, this magnitude of coverage over a four-year period would be almost the same as that achieved by the aggregated State and Commonwealth funding over the past 20 years. Its importance as a potential turning point in the government's attitude to the resources sector cannot be understated.

However, it is just as important that this level of funding be viewed in the context of the challenge faced by Western Australia in providing appropriate-resolution pre-competitive airborne geophysical data coverage over the entire state. Table 1 compares the current funding program compared with recommended levels from the recent reviews.

Although the current funding program is a necessary and welcome starting point, it is only half the lowest recommendation for pre-competitive airborne geophysical coverage of the State. It is a far cry from the proposals of the Prosser Inquiry and the MEAA SLG.

Table 1. Current WA funding program compared with recent recommended levels ($ million)

Review	*Magnetic/ radiometric*	*Gravity*	*Total*	*Timeframe (years)*	*$/year*
Fardon (2000)	$60	$14	$74	7	$10.5
Bowler (2002)	–	–	$24	6	$4.0
Prosser (2003)[a]	$22	$100	$122	10	$12.2
SLG (2003)[b]	–	–	$85	10	$8.5
Current program	**–**	**–**	**$12**	**4**	**$3.0**

NOTES: (a) The Prosser Inquiry recommendations did not mention specific dollar sums or time frames. The sums shown are estimates of the cost of the recommendations based on the following assumptions:
Rec. 6: Funds 'to accelerate onshore pre-competitive data acquisition programs'. The assumption is made that this means to complete coverage of remaining areas of the country with magnetic and radiometric surveys at 400 m line spacing or better. In Western Australia this is assumed to be 70% of the State, requiring 4.4 million line-kilometres of survey at an estimated cost of $5 per kilometre
Rec. 8: 'Conduct an airborne gravity gradiometry survey of the Australian landmass'. Gravity gradiometry surveys with the Falcon™ system mentioned by Prosser require a line spacing of not more than 500 m to be effective. Other systems may be able to utilize larger line spacings. At an assumed line spacing of 1 km, a nationwide survey would cost $600 million at present acquisition costs or $300 million allowing for a 50% reduction in cost for surveys of this size. The cost for Western Australia is assumed to be one third of this or $100 million. It is unlikely that such a program could be completed in less than 10 years with present supply capacity
(b) SLG Recommendation 8: Commonwealth/State co-funding of $25 million per year to 2014. One third for Western Australia, on the basis of its proportional area, is $85 million

But even these do not go far enough. It is not sufficient for Australia and Western Australia to simply play 'catch-up'. We must play 'leap frog'!

The dollar sums for the recommendations of the Prosser and SLG reviews were cast in a whole-of-Australia context. In contrast, the more moderate recommendations from the Fardon task force were constrained by what might be funded by the State alone. Combining the visions of all of these, Table 2 shows a coverage scenario that is challenging but achievable. The costs may seem high, but the total over eight to ten years is a fraction of the direct payments of royalties, rentals, and other taxes paid in a single year by the resources sector in Western Australia to the State and Commonwealth governments.

Table 2. Ambitious 10-year airborne geophysical coverage scenario in WA

	Magnetic and radiometric surveys[a]				*Gravity/Gradiometry*			*AEM*[b]
Resolution (m)	100	200	400	**Total**	500	1000	**Total**	**500**
Area (% of WA)	30	25	10	**65**	50	50	**100**	**50**
Area (km^2 × 1000)	750	625	250	**1 625**	1 250	1 250	**2 500**	**1 250**
Line-km (× 1000)	7 500	3 125	625	**11 250**	2 500	1 250	**3 750**	**2 500**
Cost ($ million)	38	16	3	**56**	100	50	**150**	**75**
Time frame (years)				**8**			**10**	**8**
Total cost								**$280 million**

Assumptions	*Magnetic and radiometric*	*Gravity*	*AEM*
Cost ($/line-km) (Gravity = 40% of present rates; AEM = 50%)	5	40	30
Acquisition rate (km per year per aircraft)	250 000	150 000	150 000
Survey aircraft (per year)	6	3	2

NOTES: (a) Assumes that there is existing coverage at 400 m resolution over 35% of the State
(b) AEM = Airborne electromagnetic surveys, mentioned but not recommended by the Fardon Task Force

Plainly, the scope of the current initiative is insufficient to come close to a program of this magnitude. As mentioned above, the current State funding alone will be insufficient to complete even basic 400 m-resolution magnetic and radiometric coverage of the State. While there is every hope that the MEAA will result in a major injection of Commonwealth funding, there is no guarantee that this will occur and it is critical that the limited State funding be used to optimum effect.

GSWA data-acquisition strategy

The GSWA strategy for acquisition of regional geophysical data concentrates on optimum use of the current funding while keeping options open to take advantage of any additional funding from the Commonwealth or State governments.

Complete aeromagnetic coverage of the entire State at sub-500 m resolution is a major goal of GSWA. The existing 1:250 000 geological mapping, conducted mostly in the 1960s and 70s, is nearing the end of its useful life and it will be a long time before re-mapping at 1:100 000 scale — the focus of the current GSWA field-mapping program — has sufficient extent to become the definitive coverage, except over limited areas. Airborne magnetic and radiometric data and other remotely-sensed spectral data are being used to complement and enhance the existing 1:250 000-scale geology, and geological re-interpretation on the basis of data from the newer technologies effectively extends the useful life of this mapping. It is recognized that 400 m is at the outer limits of appropriate resolution for this scale of presentation, but it is considered that the benefits to be gained from a statewide coverage will outweigh the advantages of more-detailed surveys over restricted areas.

In order to maximize data coverage, resolution, and use, the GSWA geophysical-data strategy seeks to lower the unit cost of acquisition to the State by:

- encouraging private exploration companies to make their data publicly available;
- acquiring existing commercial and proprietary data of suitable quality and integrating them with new survey data rather than over-flying these areas;
- encouraging other State agencies, land use organizations, and exploration companies to apply their funds as appropriate to in-fill GSWA regional surveys with higher resolution surveys (thus taking advantage of lower survey rates that can be obtained for large survey contracts); and
- working closely with Geoscience Australia so that State funds are combined with any Commonwealth funds that can be directed to Western Australia, in order to fly larger survey blocks at lower per kilometre rates.

Because the current funding cannot be used to complete coverage of the State with any technique at the preferred resolution, it becomes important to attain best use of the data that exist at poorer resolution. To this end, GSWA will seek to acquire complementary datasets that might provide the control for better interpretations of wider line spacing data and allow workers to extrapolate interpretations from the more detailed coverage areas to the more poorly defined areas.

GSWA four-year plan within the current funding program

The primary objective for the program is to complete 400 m-resolution airborne magnetic coverage over areas where Precambrian rocks are exposed or within 300 m of the surface. All new surveys will also include radiometric data acquisition.

The provisional flying program is shown in Figure 6 with currently planned prioritization for surveys. These priorities may be modified as the program proceeds and circumstances change.

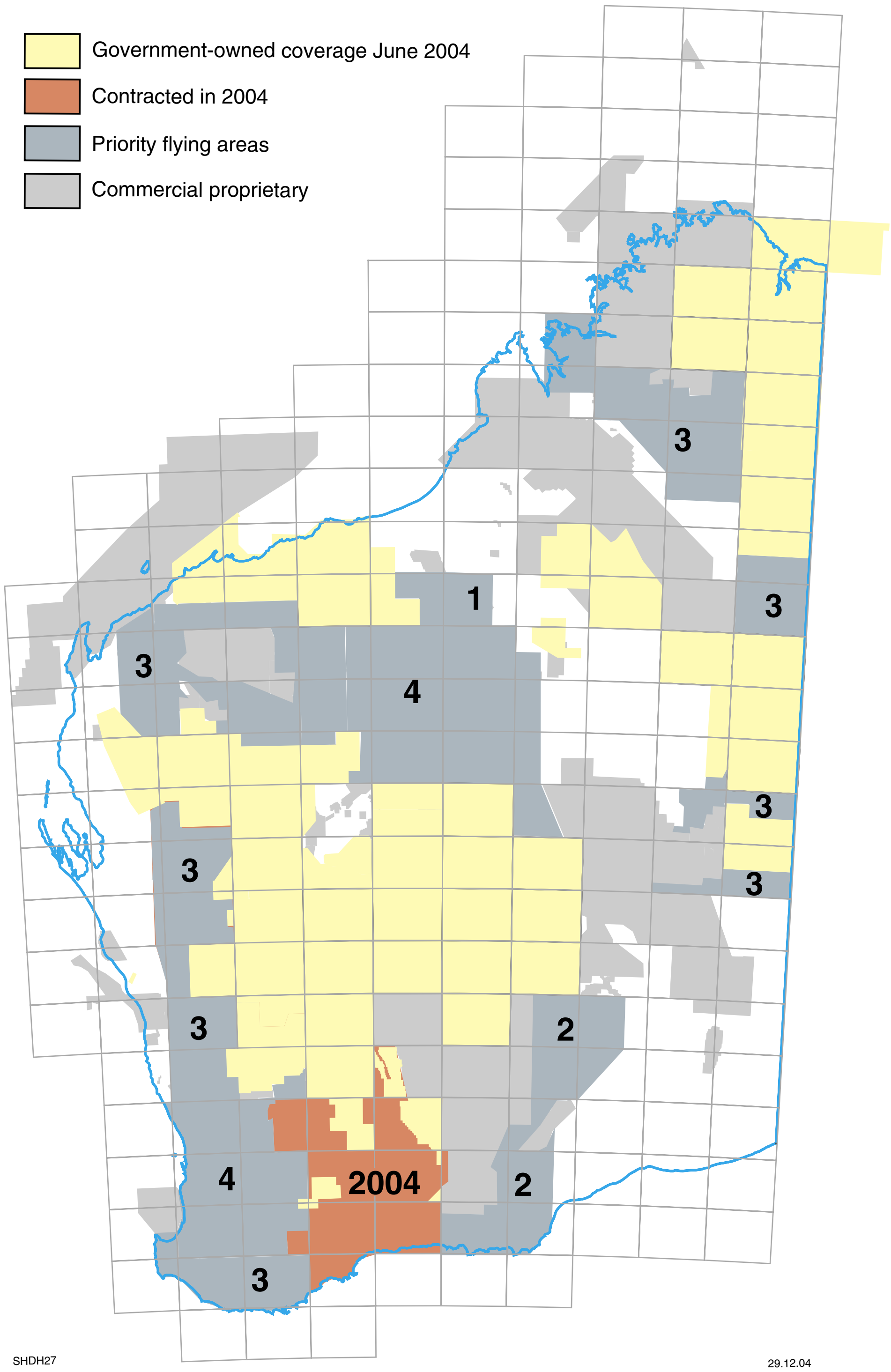

Figure 6. Priority areas for airborne magnetic and radiometric coverage 2004–2008

Survey contracts were let in July 2004 to acquire data in the southern Yilgarn. Together with the purchase and integration of existing company data, the surveys will provide coverage over an area of approximately 112 000 km^2, or 4% of the total area of the State, in a region extending from Kellerberrin to Ravensthorpe. Final data from these surveys should become available from late 2004.

Remaining priority areas include the Murchison–Gascoyne region, the eastern wheat belt, the Albany–Fraser Orogen between Esperance and Warburton, the Musgrave–Arunta region on the Western Australia border, and the west Kimberley. As funds permit, existing commercial and proprietary datasets of adequate quality will be purchased to integrate with the new data and add to the government-owned data inventory.

In addition to aeromagnetic and radiometric data, there are plans for collection of other data of interest to mineral explorers, such as orthophotography and hyperspectral-sensing, geochemical, and gravity surveys, and, in conjunction with Geoscience Australia and the Australian National Seismic Imaging Resource, some deep crustal seismic traverses in key areas of the State.

In the agricultural areas of the western wheat belt, it is hoped that additional State funds and matching Commonwealth funds from the National Action Plan for Salinity and Water Quality program might become available. If this happens, it will be possible to increase the magnetic and radiometric survey resolution in those areas for the benefit of agriculturalists, natural resource management groups, and mineral explorers alike. The target resolution in these areas is 100 m line spacing.

If matching Commonwealth funds from the MEAA become available, completion of aeromagnetic and radiometric coverage over the Phanerozoic basins becomes achievable, as does increased gravity coverage (whether ground or airborne).

The importance of the new data for enhancing existing geological mapping has not been overlooked, and new geological interpretations will be undertaken in areas of new geophysical coverage.

All data and interpretations will be released as soon as they are available.

Conclusions

Although a number of factors impact on exploration activity, there is no doubt the provision of pre-competitive, regional geoscience information is an important mechanism to attract private exploration investment to an area. The question of what constitutes the appropriate resolution for pre-competitive datasets is subjective and reduces to a trade-off between extent of coverage and degree of detail.

As a consequence, it can be difficult to determine the 'right' level of government funding for the provision of pre-competitive geoscience data. That difficulty is illustrated by the fact that four government reviews between 2000 and 2003 made recommendations for expenditure on pre-competitive airborne geophysical data over Western Australia that ranged from $24 million over six years to $122 million over ten years.

When arguments can be made for even higher expenditures than these, it is not surprising that government, when faced with such a variable response from its advisors, takes the minimal expenditure approach that has characterized Western Australian Government investment in regional geophysical surveys.

Clearly, the fact that all the recent reviews recommended dramatically increased levels of funding for the provision of statewide geophysical surveys has had an effect. The Western Australian State Government's current funding of $12 million for a four-year regional geophysical survey program is more than twice the amounts allocated by previous State Governments during the past 20 years. It will make a significant difference to the level of pre-competitive coverage of airborne magnetic and radiometric data in Western Australia. However, it is only a fraction of the sum needed to complete appropriate-resolution geophysical coverage of the State.

The reality is that investment in comprehensive, appropriate-resolution geoscience coverage is an investment in the State's infrastructure, in the same way as is investment in ports, roads, or the education system, and should be considered as such.

GSWA has a 10-year vision for pre-competitive geophysical coverage of Western Australia that includes, as a minimum:

- complete sub-500 m resolution magnetic and radiometric coverage over the entire state, and sub-250 m coverage of areas where Precambrian basement rocks are within 300 m of the surface; and
- complete 1 km-resolution airborne gravity or gravity gradiometry coverage over the entire State.

The vast size of Western Australia makes this a challenging, but achievable, goal. For it to become a reality, it requires a sustained commitment by State and Commonwealth governments; a commitment that transcends short-term political and economic cycles. It will need the Western Australian State and Commonwealth governments to have the same level of faith in the resources sector and make the same calibre of investment decisions that they are calling on private explorers to do.

Without such whole-hearted commitment, the vision of comprehensive geophysical coverage of Western Australia will remain nought but a pipe dream.

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